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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAM OF THE

MADISON MEETING

AT

THE UNIVERSITY OF WISCONSIN

MADISON, WISCONSIN

JUNE 22 AND 23, 1937

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The American Physical Society

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JUNE 4, 1937 Vol. 12, No. 3

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

MADISON MEETING, JUNE 22–23, 1937

(Central Standard Time)

THE 214th regular meeting of the American Physical Society will be held at Madison, Wisconsin on Tuesday and Wednesday, June 22 and 23, 1937 on the campus of the University of Wisconsin. The sessions will be held in the physical laboratory, Sterling Hall, on Charter Street just north of University Avenue.

Symposium on Generation and Studies of High Frequency Currents of Centimeter Range. On Tuesday afternoon at two o'clock in Room 113, Sterling Hall, there will be held a symposium of invited papers on *Generation and Studies of High Frequency Currents of Centimeter Range.* The speakers on this symposium will be Professor Neil H. Williams of the University of Michigan, Dr. G. C. Southworth of the Bell Telephone Laboratories Inc., Dr. G. R. Kilgore of the RCA Manufacturing Company, and Dr. A. L. Samuel of the Bell Telephone Laboratories Inc.

Registration. Registration (50¢ per family) will take place in the Memorial Union Building on Lake Mendota at Park and Langdon Streets.

Accommodations. Insofar as possible, visiting members of the Society will be housed in Chadbourne Hall, a university dormitory at Park Street and University Avenue. About one hundred rooms are available with the usual dormitory facilities, and both men and women will be accommodated. The dormitory will be open Monday afternoon, and may be occupied until Thursday morning. The rate will be $1.50 per person per day. *Reservations should be made at once.* Meals will be served in the cafeteria on the ground floor of the Memorial Union. The terrace (lake shore) is particularly recommended in fine weather.

Those who prefer hotel accommodations should make reservations by writing directly to the hotel. (Minimum rates are shown for single and double rooms, respectively.)

Hotel Loraine, Washington Avenue and Fairchild Street—$2. and $4.
Park Hotel, Carroll and Main Streets—$1.50 and $3.00
Hotel Belmont, Pinckney and Mifflin Streets—$2. and $3.

The hotels are in the downtown district near the state capitol, one mile from the campus. Taxi fare is 10 to 25¢.

Dinner. There will be an informal dinner in Tripp Commons, Memorial Union, at 7 o'clock on Tuesday evening. Tickets at $1.25 each may be purchased at the registration desk until 2 o'clock on Tuesday afternoon. *Advance registration is urgently requested.*

Entertainment. Mrs. C. E. Mendenhall, 205 North Prospect Avenue, invites all members of the society and their wives and friends to tea at 4 o'clock on Tuesday.

The following entertainment has been arranged by the local committee:

For all: A visit to the United States Forest Products Laboratory on Wednesday afternoon; a picnic on Observatory Hill at 6:30 P.M. on Wednesday; a trip to Wisconsin Dells on Thursday. Members may obtain information upon registration as to special arrangements for golf, tennis, boating, and swimming (bring your own suits).

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Particularly for women guests: A drive around Lake Mendota at 10 o'clock on Tuesday morning; a boat ride on Lake Mendota at 10 o'clock on Wednesday morning. Visiting ladies will be guests of the local members of the society at a complimentary luncheon at 12:45 P.M. on Wednesday at the University Club. If desired, provision will be made for the care of children.

Transportation. No arrangements have been made for reduced railroad rates on the convention plan. It is advisable for all who are planning to attend this meeting to consult their local ticket agent for information regarding the possibility of summer excursion fares and other reduced rates.

Summer Meeting at Denver. The summer meeting on the Pacific Coast will be held in affiliation with the American Association for the Advancement of Science at Denver, Colorado, June 21–26, 1937.

General Rules Relating to Papers

Only those titles of papers shall be listed on the preliminary program of a meeting of the Society for which abstracts ready for publication are in the hands of the Secretary.

On December 28, 1936 the Society voted that:

No papers may be accepted for presentation at any meeting of the Society subsequent to the closing date stated in the printed call for that meeting.

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program. (A paper presented by two or more authors is assigned to the first named author.)

All supplementary papers will be grouped according to subject matter and will be called for at their appropriate sessions only, these sessions to be designated on the program. The presiding officer may assign a reduced time to these papers or may in his discretion call for them to be read by title only.

Except by special vote of the Society, the maximum allowance of time for the presentation of a paper shall be ten minutes. The presiding officer shall enforce this rule.

Titles and abstracts of the papers to be presented are given in the following pages. These abstracts have not been corrected by the authors. After correction the abstracts will be published in an early number of the *Physical Review*. Authors should send corrections to the Publications Manager, The American Institute of Physics Incorporated, 175 Fifth Avenue, New York, N. Y.

Other meetings for the current season are as follows:

215. June 25–26, 1937. Denver, Colorado. Pacific Coast Section in affiliation with the A.A.A.S.
216. November 26–27, 1937. Chicago, Illinois.
217. Pacific Coast Meeting. December 1937.
218. December 28–30, 1937. Annual Meeting. Indianapolis, Indiana.

W. L. Severinghaus, *Secretary*
Columbia University, New York, N. Y.
June 4, 1937.

CALENDAR

Central Standard Time

Tuesday morning, June 22

10:00 o'clock: Sterling Hall: Room 113: Papers 1–15. See pages 6–9.

10:00 o'clock: Drive around Lake Mendota.

Tuesday afternoon, June 22

12:30 o'clock: Sterling Hall: Room 12: Meeting of the Council.

2:00 o'clock: Sterling Hall: Room 113: Symposium on *Generation and Studies of High Frequency Currents of Centimeter Range*. See page 9.

4:00 o'clock: Tea: Mrs. C. E. Mendenhall, 205 North Prospect Avenue.

Tuesday evening, June 22

7:00 o'clock: Memorial Union: Tripp Commons: Dinner.

Wednesday morning, June 23

10:00 o'clock: Sterling Hall: Room 113: Papers 16–25. See pages 9–11.

10:00 o'clock: Sterling Hall: Room 111: Papers 26–35. See pages 11–13.

10:00 o'clock: Boat ride on Lake Mendota.

Wednesday afternoon, June 23

12:45 o'clock: University Club: Complimentary luncheon for visiting ladies.

2:00 o'clock: Visit to the United States Forest Products Laboratory.

Wednesday evening, June 23

6:30 o'clock: Picnic on Observatory Hill

Thursday, June 24—Trip to Wisconsin Dells.

PROGRAM

TUESDAY MORNING AT 10:00 O'CLOCK

Sterling Hall, Room 113

Papers No. 1, 2 and 3 will be read by title.

1. Acoustical Detection of Purely Mechanical Vibrations in Quartz Plates.* W. H. PIELEMEIER, *Pennsylvania State College.*—Correlation of extensive results obtained from Y-cut quartz plates with those obtained from X-cut and other plates leads to the conclusion that certain thickness vibrations may produce a considerable acoustical effect while their electrical effect may be absent or difficult to detect by ordinary methods. In order to be maintained such vibrations must be mechanically coupled with one of the piezoelectric modes of the plate having nearly the same frequency. The latter may be a shear or a longitudinal vibration. Obviously thickness vibrations are most effective in producing sound waves emanating from the largest face of the plate. If these are purely mechanical an electrical engineer would probably not suspect their existence. A simple method to obtain their frequency is to measure the wave-length that they produce in a gas in which the supersonic velocity is known. As the most convenient gas is air very careful velocity measurements were made with *known* frequencies in air at barometric pressure, at constant temperature and over a range of humidities. Two anomalous humidity regions exhibiting dispersion were discovered. These partly account for the rather *large* disagreements amongst the velocity measurements made by many reliable investigators.

* To be read by title.

2. Supersonic Dispersion in Air.* W. H. PIELEMEIER, *Pennsylvania State College.*—The above cited anomalous humidity regions were found at 30°C and a frequency of 528.4 kc/sec. Scattered measurements were also made at other temperatures and frequencies. Knudsen's[1] curve relating critical absorption frequency and H_2O concentration in oxygen was extrapolated to this frequency. One of the above humidity regions was found at 45 percent of the extrapolated critical H_2O concentration for oxygen at 528.4 kc/sec. For lower frequencies Knudsen[1] reported approximately half as much H_2O concentration for air as for O_2. Sinnes and Roseveare[2] show experimentally that in O_2 a velocity dispersion accompanies an absorption peak as expected from theory. The observed velocity shift in this region fits that calculated for the O_2 concentration in air. The shift in the other observed anomalous region fits that for approximately the CO_2 concentration in air reported by Reid.[3] The location of this region is in harmony with the measurements of other investigators.

* To be read by title.
[1] V. O. Knudsen and L. Obert, J. Acous. Soc. Am. **7**, 249 (1936).
[2] L. S. Sinnes and W. E. Roseveare, J. Chem. Phys. **4**, 427 (1936).
[3] C. D. Reid, Phys. Rev. **35**, 814 (1930).

3. Alternating Current Impedance of *Nitella.* H. J. CURTIS AND K. S. COLE, *Columbia University.*—The fresh water plant *Nitella* has single cells 10 to 20 cm long and about 0.5 mm in diameter. A single cell may be placed in various electrolytes between two electrodes parallel to the cell axis and the alternating current impedance measured at frequencies from 30 to 2,500,000 cycles per second. The data indicate that the thin cellulose envelope has a specific resistance of about 1000 ohm cm which is nearly independent of the conductivity of the external electrolyte. Inside of this cellulose is the physiological membrane which is found to be virtually nonconducting and to have a capacity of 0.9 to 1.0μf/cm^2 at 5000 cycles with a phase angle of 80°. The specific resistance of the sap, which nearly fills the interior, may be calculated from the measurements on the living cells, but such values disagree sharply with the 60 ohm cm obtained on extracted sap. The difference may be due to the presence, in the living cell, of the chloroplasts which seem to have a complicated electrical structure.

* To be read by title.

4. A Thermo-Stromuhr for Measuring Blood Flow. J. F. HERRICK AND E. J. BALDES, *Divisions of Experimental Medicine and Biophysics, The Mayo Foundation, Rochester, Minnesota.*—The physiological processes of bodily tissues depend upon an adequate blood supply. An accurate method of measuring blood flow to a given region or organ offers a means of studying some of these physiologic processes. Also, the heat-regulatory mechanism and the blood-pressure regulatory mechanism depend, to a large extent, on blood flow. To obtain a method which measures the flow of blood without the disturbing factor of anesthesia and without interfering with the normal relationships in the intact dog is the ultimate goal of any investigator in this field. In 1928, Rein[1, 2] described an ingenious indirect method for measuring blood flow in the anesthetized dog. We have been using this method for several years and have applied it to the intact animal. The purpose of the present paper is to report an analysis of physical principles involved in this method. We consider the following: (1) Certain criticisms of Rein's description of the nature of heat transfer; (2) discrepancies of the method when measuring small flows; (3) limitations of the method; (4) a modified thermostromuhr; (5) dependence of the method on the character of the flow.

[1] H. Rein, Zeits. f. Biologie **87**, 394–418 (1928).
[2] H. Rein, Abderhalden Handbuch der biol. arbeit. **8**, 693–716 (1928–35).

5. Thin-Film Lubrication of Non-planar Surfaces of Finite Width. SELBY M. SKINNER, *Columbia University.*—The classical treatment of thin film lubrication by Sommerfeld is restricted to surfaces of infinite width, thus neglecting escape of the lubricant along the lateral edges of the bearing. This leakage reduces materially the total load which can be supported by the bearing. The plane bearing of finite width has been treated by Michell and others, leading to the development of the Michell thrust bearing. In practice, however, the bearing surface may be curved. The theory is here extended to two general classes of curved bearing surfaces of finite width. A general method of solution is given, and the exact solutions for several cases are developed. The effect of side leakage, the total load which can be supported, the frictional resistance, and the total quantity of lubricant required are determined. The theory for sector-shaped surfaces is also extended to a case in which the dependence of film thickness on distance from the center of rotation may be treated.

6. Determination of Fiber to Void Ratio of Wood Pulp Paper by Electrical Methods. E. W. GREENFIELD, *Anaconda Wire & Cable Co., Hastings-on-Hudson, New York.*—Application of the method of mixtures has been attempted for determining, by electrical means, the ratio of fiber to voids in a number of commercial wood pulp cable papers. This problem has its important bearing on the paper industries' partial fraction measurements as well as on the oil to paper ratios of impregnated paper high-voltage cables. Separate measurements, under uniform conditions, of the dielectric constants of dry paper, oil and impregnated paper yield sufficient experimental data to enable the calculation of fiber to oil ratio as well as the dielectric constant of the fiber itself. The principal difficulty in using this method is the necessity of an assumed geometric distribution of the cellulose fibers and the voids, and this is of course unknown. Previous attempts* to use this method assumed, for simplicity of calculation, a two-layer series dielectric. The present paper gives results using four different distributions of fiber and void: series layers, parallel layers, series-parallel layers, and cylinders of voids in a medium of solid cellulose perpendicular to the electric field. Correlation of the values obtained for each dielectric distribution with experimental extraction and theoretical density determinations yields interesting data on each paper studied.

* J. B. Whitehead, Trans. A. I. E. E. **2**, 667 (1933).

7. Dynamic Characteristic Curves of Glow-discharge Tubes. HERBERT J. REICH AND WALLACE A. DEPP, *University of Illinois.*—The dynamic current-voltage curves of glow-discharge tubes are observed by means of a cathode-ray oscillograph. The technique differs from that ordinarily used in that the manner in which the current varies with time is under control. This is accomplished by the use of a vacuum tube to limit the current passed by the discharge tube. The rate at which the current rises and falls, the frequency of repetition of the current cycle, and the interval between cycles can be varied at will by changing the waveform of the voltage applied to the grid of the control tube. The marked departure of many of the characteristic curves from the form commonly assumed is explainable on the basis of the time taken for ionization and deionization of the gas.

8. High Pressure Arc Phenomena. C. G. SUITS, *General Electric Company.*—A comprehensive investigation of the properties of the electric arc in the high pressure range has been partially completed. Several pressure chambers and some new measurement methods allow observations of total arc voltage e as a function of current i up to 3600 atmospheres; e, electric gradient E (volts cm^{-1}), current density I (amp. cm^{-2}) assumed constant over the arc cross-section, and light output up to 220 atm. In gases of 99 percent purity the measurements extend, in N_2 from 1–1200 atm., H_2 from .01–200 atm., A from 1–100 atm., and He from 1–200 atm. for Cu, W, and C electrodes. In all gases e, E, and I increase with pressure; at constant pressure e, E, and I increase with gas in the order Hg, A, N_2, He, H_2. The pressure effect is such that e increases approximately 2 times, E 3 times, and I 15 times when p increases 100 times. Since $(n^2/N)\sim(I/E)^2$ for each gas, the gas temperature can be calculated from the Saha equation for an assumed ionization potential. At 1 atm. and 10 amp., the following temperatures, °K, are obtained: A, 6500; He, 5900; Hg, 5400; N_2, 6100 (measured by sound velocity); and N_2 at 100 atm., 7100. The dependence of arc temperature on current and arc length is known to be small from sound velocity measurements. The arc temperature is thus relatively constant over a large range of experimental conditions. The interpretation of the measurements in terms of conduction and convection heat loss from cylinders will be treated in a paper now in preparation. Because the arc temperature is relatively constant, a generalization which predicts the trends with pressure and gas is: *The arc properties E and I are the same in various gases at the pressure at which the conduction and convection heat loss is the same.* Because the temperature is not perfectly constant, some anomalies occur. The measurements of I, and especially E, are subject to considerable uncertainty due to experimental error and lack of reproducibility of experimental conditions, and are to be regarded as tentative in absolute magnitude but correct in trend. Initial data have been obtained with a new method of simultaneously measuring e, I, and E as $f(i)$ with a relatively high accuracy.

9. Photoelectric Sensitization of Aluminum. LOUIS P. THEIN, S.M., *St. Louis University.* (*Introduced by J. J. Brady.*)—It is well known that many metal surfaces become more sensitive photoelectrically after exposure to a hydrogen glow discharge. In the present work, it is shown that no sensitization occurs if the aluminum target is made the *anode* of the discharge. The increase in photo-current, with the target as cathode, is found to be dependent on the time of the glow discharge and the pressure of the hydrogen. If the target is not outgassed, a rapid decay in photo-current is noted after sensitization, because of the diffusion to the surface of gas contained in the body

of the metal. Results indicate that this sensitization is due mainly to a "clean up" of the surface of the oxide-coated aluminum, and the upper limit of this type of sensitization is fixed by the yield of pure aluminum. Another type of sensitization occurs when small amounts of dry air are admitted in contact with freshly distilled aluminum. The sensitivity here is found to be as much as 6 or 7 times as high as that of pure aluminum or as much as 800 times that of an untreated piece of aluminum. The current-voltage data from freshly distilled aluminum yield a curve which fits well upon the theoretical curve of the DuBridge theory. The curves from the surfaces sensitized with air show no agreement with the theory. The threshold for pure aluminum is at 2900A.

10. Temperature Effects in Photoelectric Emission. R. J. CASHMAN, *Northwestern University.*—Fowler's simple photoelectric theory gives for the spectral distribution function $I = CT^2\varphi[(h\nu - h\nu_0)/(kT)]$. For certain values of ν the effect of the T term is much more pronounced for emission at different temperatures than the φ term, a situation unlike that in Richardson's equation for thermionic emission. At $\nu = \nu_0$, $I = C\pi^2/12T^2$. All published data on clean metals show that the variation of I with T is smaller than that predicted by a T^2 law, the value of the exponent changing from about 1 to 1.6. Although one must not overlook the possibilities of a transmission probability which would modify the theory it seems at present that the apparent departure from a T^2 law can be adequately accounted for by introducing a small positive temperature coefficient of the work function. Let $h\nu_0$ and $h\nu_0 + \Delta w$ be the work functions at T_0 and T, respectively. The currents at $h\nu = h\nu_0$ will be, according to Fowler's theory,

$$I_0 = C\pi^2/12T_0^2, \qquad I = CT^2\varphi(\Delta w/kT),$$

where φ is a universal function of the argument. Values for the coefficient $\Delta w/(T - T_0)$ from 3 to 10×10^{-5} ev/deg. will account for the apparent departure of existing data. A positive temperature coefficient also predicts that the current-frequency curves for higher temperatures will cross those for lower temperatures for $\nu \gg \nu_0$, an experimental fact which caused considerable controversy when Fowler's theory was proposed.

11. Quantum Mechanical Calculation of the Lattice Energy of NaCl. ROLF LANDSHOFF, *University of Minnesota.*—Starting from a wave function in the form of a determinant of single-electron wave functions, the lattice energy of the NaCl crystal, consisting mainly of the electrostatic and the exchange energy, is calculated numerically. For single-electron wave functions we take the orbitals at the respective ions, which have been calculated by Fock[1] and Hartree.[1, 2] These orbitals take into account the exchange interaction between the electrons in a single ion. This gives a considerable improvement over the calculation[3] based on orbitals of the original Hartree type in which this exchange is neglected.[4] An attempt to calculate the polarization energy along the lines of Schroedinger's second order perturbation theory yielded values much too large. Therefore only the van der Waals part of the second order energy was included in the calculation. The results are: lattice energy 182 kcal./mole, lattice distance 2.78A and compressibility $4.35 \cdot 10^{-12}$ bar^{-1}.

[1] V. Fock and Mary J. Petrashen, Zeits. d. Sowjetunion **6**, 368 (1934).
[2] D. R. Hartree and W. Hartree, Proc. Roy. Soc. **A156**, 45 (1936).
[3] R. Landshoff, Zeits. f. Physik **102**, 201 (1936).
[4] D. R. Hartree, Proc. Roy. Soc. **A141**, 282 (1933).

12. A Theory of Liquid Structure. JOSEPH HIRSCHFELDER, DAVID STEVENSON AND HENRY EYRING, *Princeton University.*—A simple model of the liquid is used to extend the equation of state previously obtained and to treat the process of fusion, viscous flow, and binary liquid systems. Our equation of state which applies to dense liquids has been fitted on to Happel's modification of van der Waals' equation to give a single equation applicable over the entire range from gas to liquid. A liquid differs from a solid in that the surplus volume in one part of the liquid becomes available in another part without an activation energy appreciable as compared to kT. This communal sharing of volume gives rise to an entropy of fusion R modified of course if there are other structural changes. Other entropy changes arise from expansion, changes of librations into free rotations and from polymerization. Double molecules held together by van der Waals forces are considered quantitatively and used in the explanation of viscous flow and deviations of the equation of state at the critical point. An explicit expression is given for the osmotic pressure of a binary liquid mixture. "Holes" are used to complete the analogy between critical phenomena for a one-component system and critical solution phenomena of binary liquids. In binary liquids the presence of a lower critical solution temperature above which two phases exist results from hydrogen (or analogous) bonds or bridges between unlike molecules which prevent free rotation. The critical mixing point coincides with the onset of free rotations which disrupt these bonds.

13. On the Magnetic Susceptibilities of Ti, V, and Cr Alums. J. H. VAN VLECK, *Harvard University.*—Lipson and Beevers' x-ray measurements on the alums seemingly indicate a field around the paramagnetic ion of trigonal, in fact nearly cubic symmetry.[1] With such a model, however, the excited states of Cr^{+++} cannot have the gyromagnetic ratio $g = 2$ *uniformly* revealed by the Zeeman measurements of Spedding and Nutting.[2] Also it is then practically impossible to understand how the alums of Ti and V can *both* obey Curie's law with approximately the spin-only value of the susceptibility.[3] The dilemma is solved by using Jahn and Teller's neat observation that with orbital degeneracy the equilibrium position is "off-center," so that the symmetry is lowered and this degeneracy lifted.[4] Thus one can have a rhombic splitting of the order 10^3 cm^{-1} demanded by the susceptibility data and still retain the higher x-ray symmetry. The clusters about a given ion "resonate" through different rhombic arrangements and the average distribution revealed by x-rays can be cubic although instantaneously the field is only rhombic.

[1] Proc. Roy. Soc. **148A**, 664 (1935).
[2] Spedding and Nutting, J. Chem. Phys. **3**, 369 (1935).
[3] Cf. Siegert, Physica **3**, 85 (1936).
[4] Jahn and Teller, Phys. Rev. **49**, 874 (1936): Proc. Roy. Soc. in press.

14. Conductivity of Monovalent Metals. J. BARDEEN, *Harvard University.*—The conductivity of monovalent metals is computed from the Bloch theory under the assumption that the wave functions of the electrons are nearly the same as those of free electrons throughout the major part of the volume. The perturbation potential resulting from the Debye elastic waves, which produce transitions between the electronic states, is the sum of two terms: (1) the change in the total potential of the ions, which are assumed to move rigidly with the elastic waves, and (2) the change in the potential of the self-consistent field of the valence electrons. The second part tends to compensate the first. Scattering of the electrons through angles greater than $2\sin^{-1}2^{-\frac{1}{2}}$ results from the "umklapp-prozesse" of Peierls. It is shown that the probability of these transitions joins smoothly with the probability of transitions of the ordinary type, so that the probability is a continuous function of the angle of deflection, and transitions through all angles are possible. Comparison with experiment is made through Bethe's interaction constant C, which is a measure of the average scattering power of the elastic waves. The table gives the theoretical and experimental values of C/ζ, where ζ is the Fermi energy.

	Na	K	Cs	Rb	Cu	Ag	Au
C/ζ (theor.)	0.77	0.77	0.80	0.82	0.80	0.83	0.90
C/ζ (exp.)	0.77–1.04	0.87–1.04	1.3	1.6	1.32	1.21	1.30

15. The Gamma-Ray Spectrum of B^{10}. P. GERALD KRUGER AND G. K. GREEN, *University of Illinois.*—The gamma-rays from beryllium bombarded with deuterons have been analyzed by the examination of the Compton electrons ejected from a thin mica foil. A set of 1200 expansion chamber photographs yielded 480 acceptable tracks which were grouped and analyzed by the method of Richardson and Kurie.[1] The spectrum consists of six lines at 0.42, 1.15, 1.44, 2.17, 2.86 and 3.20 Mev±0.10 Mev. Bonner and Brubaker[2] have investigated the neutron spectrum of this reaction and found excited levels of the B^{10} nucleus at 0.55, 2.15 and 3.45 Mev±0.20 Mev. The set of gamma-ray lines represents all possible transitions between these levels and the ground state. Energy level values which best fit the gamma-ray spectrum are 0.5, 2.1 and 3.3 Mev, which is in good agreement with the results of Bonner and Brubaker.

[1] Richardson and Kurie, Phys. Rev. **50**, 999 (1936).
[2] Bonner and Brubaker, Phys. Rev. **50**, 308 (1936).

TUESDAY AFTERNOON AT 2:00 O'CLOCK

Sterling Hall, Room 113

SYMPOSIUM

ON

GENERATION AND STUDIES OF HIGH FREQUENCY CURRENTS OF CENTIMETER RANGE

1. **The Production and Absorption of Electromagnetic Waves Having Length from 2 cm to 6 mm.** NEIL H. WILLIAMS, *University of Michigan.*
2. **Some New Experimental Methods Applicable to Extremely High Frequencies.** G. C. SOUTHWORTH, *Bell Telephone Laboratories Inc.*
3. **The Magnetron as a High Frequency Generator.** G. R. KILGORE, *RCA Manufacturing Company.*
4. **The Negative Grid Tube as a High Frequency Generator.** A. L. SAMUEL, *Bell Telephone Laboratories Inc.*

WEDNESDAY MORNING AT 10:00 O'CLOCK

Sterling Hall, Room 113

Paper No. 16 will be read by title.

16. Energy Loss of High Energy Beta-Rays in Lead.* J. J. TURIN AND H. R. CRANE, *University of Michigan.*—With the beta-rays from Li^8, we have continued our cloud chamber measurements[1] of the loss of energy of electrons in passing through lead, and have extended the data up to 11 Mev. A preliminary measurement of 415 tracks indicates the following losses in a ½ mm lead absorber.

INCIDENT ENERGY	AVERAGE LOSS
4 to 6 Mev	1.82 Mev
6 to 8 Mev	2.49 Mev
8 to 11 Mev	2.70 Mev

These values, like our values for the lower energies, are

roughly 50 percent greater than predicted theoretically for ½ mm lead. Because of nuclear scattering in the lead the actual length of path of the electrons is expected to be appreciably greater than the thickness of the lead. A path length-thickness ratio of 1.5 might not be unreasonably large, and would bring the experimental values into fair agreement with theory.

* To be read by title.
[1] Abstract, Washington Meeting, 1937.

17. The Disintegration of Be by Protons and Deuterons. J. H. WILLIAMS, R. O. HAXBY AND W. G. SHEPHERD, *University of Minnesota.*—The yield curves for Be under proton and deuteron bombardment have been observed between 100 and 250 kv. Numbers *vs.* range curves for the various deuteron disintegration products are being investigated.

18. The Gamma-Rays from B and Be Under Proton Bombardment and from Li Under Deuteron Bombardment. W. G. SHEPHERD, R. O. HAXBY AND J. H. WILLIAMS, *University of Minnesota.*—Boron under proton bombardment emits a hard gamma-ray. The resonance observed by Bothe and Gentner at 180 kv has been verified. No gamma-rays harder than background x-rays from the accelerating tube have been observed from Be under bombardment with 200 kv protons. The gamma-ray previously reported from Li under deuteron bombardment has been found from absorption measurement in lead to have an energy of 400±25 kv. This energy agrees well with the observed difference in energy between the associated proton groups.

19. Delayed Alpha-Particles from Li^7 Bombarded by Deuterons. R. B. ROBERTS AND L. R. HAFSTAD, *Department of Terrestrial Magnetism, Carnegie Institution of Washington,* AND L. H. RUMBAUGH, *Bartol Research Foundation of the Franklin Institute.*—The delayed alpha-particles emitted by Li^7 after bombardment with deuterons have been investigated, using a thin target (70 kv) deposited on a wheel which rotated continuously in the vacuum during bombardment. The alpha-particles counted were those emitted when the wheel had rotated 90° from the point of bombardment. In this manner it was possible to obtain numbers of delayed alpha-particles sufficient for accurate counting without any background of other heavy-charged particles. The excitation-curve of the delayed alpha-particles follows exactly that of the beta-particles in the voltage-range measured (550 to 950 kv) and shows the same break at 770 kv. The range-number curve of the delayed alpha-particles has been measured from 0.45 to 3.25 cm and shows a smooth, rapidly falling characteristic, with no evidence of any distinct groups of particles. If the logarithm of the number of alpha-particles observed at a given range is plotted against the corresponding energy, a straight-line relation holds over a factor of four in the energy.

20. The Range of Protons in Aluminum and in Air. D. B. PARKINSON, R. B. HERB, J. C. BELLAMY, C. M. HUDSON, *University of Wisconsin.*—With the use of the two million volt generator developed at this laboratory the range of protons in air and in aluminum has been measured as a function of proton energy up to about 2 Mev. The range in air data are in good agreement with the theoretical values of Mano at high energies but diverge considerably at energies below 0.7 Mev. The ratio of the range in air to the range in aluminum has been found to increase from a value of approximately 1000 at 200 kv to a value of 1550 at 1200 kv. From 1200 kv up to the maximum voltage available the ratio is shown to remain nearly constant.

21. On Fluctuations in Size of Multiplicative Showers. W. H. FURRY, *Harvard University.*—Recent calculations of Carlson and Oppenheimer and of Bhabha and Heitler have made it evident that many features of cosmic-ray absorption and of shower production may be accounted for by assuming the validity of the existing radiation theory up to energies enormously higher than those at which a failure of the theory was formerly suspected. Being based essentially on calculations of the *mean numbers* of secondary photons and electrons produced under given conditions, these calculations need in some cases to be supplemented by a consideration of the fluctuations around these mean values. For example, such considerations are of importance in trying to determine to what extent the observed occasional production of large showers from fairly thin layers of lead (~1 cm) can be accounted for by the multiplication hypothesis. Bhabha and Heitler suggest, on apparently inadequate grounds, that the probability of appearance of n particles is given by the Poisson law, $P(n)=(m^n/n!)e^{-m}$, where m is the mean number. Detailed consideration of some drastically simplified but still presumably apposite cases has indicated that the Poisson law does not hold, and that the actual distribution is essentially of the type of $P(n)=m^{-1}(1-m^{-1})^{n-1}$. The latter law gives definitely greater probabilities for large showers.

22. The Hard Component of Cosmic Radiation. ARTHUR BRAMLEY, *Washington, D. C.*—The experiments indicate that the particle responsible for the hard component is extremely penetrating.[1] Since its ionization is nearly normal, the radiation losses must be abnormally low for an electron of that energy. The small cross section for radiation can arise either (1) because the particle has a greater mass than an electron, or because the electron has its charge distributed over a region with dimensions $\sim 10^{-11}$ cm, or (2) because the particle, if an electron, has a spin greater than ½.[2] The radiation losses from an electron with spin greater than ½ are considerably reduced in the case that its rest mass can be neglected in comparison with the mass associated with its kinetic energy. An extrapolation of the Fermi interaction to an electron of this character would lead us to expect that the maximum interaction would occur at an energy lower than 137 mc^2. It is impossible to predict what the strength of this interaction may be. It might turn out that the maximum strength of the interaction was such that all the low energy electrons with spin greater than ½ would be absorbed into the nuclei of the medium they were traversing.

[1] Street and Stevenson, Abstract 40, Bulletin, Vol. 12, No. 2: Anderson, Science News, November, 1936.
[2] Dirac, Proc. Roy. Soc. July (1936).

23. The Scattering of Neutrons by Iron. R. F. BACHER, *Cornell University.*—The scattering of rhodium resonance neutrons by Fe has been studied by using thin and thick iron scatterers above a detector on a paraffin cylinder. It has been found that the albedo effect contributes greatly to the scattering. In order to take this into account small thick detectors were used to determine the number of neutrons passing in each direction through the interface. For 5.4 cm Fe the fraction of neutrons reflected was 0.40 while for 0.6 cm Fe the fraction reflected was 0.20. For the thick iron this reflection gives a ratio of absorption to scattering cross section $\sigma_a/\sigma_s=0.22$. From the measurements on the thin plate $\sigma_s=11\times10^{-24}$ cm².

24. On the Scattering of Neutrons by Magnetic Dipoles. OTTO HALPERN AND M. H. JOHNSON, *New York University.*—In establishing the theoretical basis for experiments previously suggested by the authors (to appear in the *Physical Review*) we have made a more detailed investigation of the scattering of neutrons by magnetic dipoles. In these calculations the atomic dipoles were treated quantum-mechanically leading to significant differences from previously suggested formulae. In general, in paramagnetic as well as ferromagnetic substances the magnetic scattering cross sections are increased because of collisions of the second kind whereby transitions of the atom are induced either among the different magnetic sublevels or to neighboring spectroscopic levels. Polarization of the neutron beam may occur not only because of interference between nuclear and magnetic scattering, but also because of the magnetic scattering alone if transitions among the magnetic sublevels are possible. The latter type may assist or diminish the former depending upon the phase change produced in the nuclear scattering (real or virtual level of the system nucleus plus neutron). Other changes in the polarization effects can be produced by spin dependent forces and the presence of isotopes. The additional transitions here discussed tend to diminish polarization effects in ferromagnetic bodies.

25. Simple Derivation of the Formula for the Total Scattering of X-Rays from a General Crystal. G. G. HARVEY, *Massachusetts Institute of Technology.*—For the case of a general triclinic crystal having any number of atoms in the unit cell there is derived a formula for the intensity of total scattering of x-rays in any direction. In those directions satisfying the Laue equations the formula reduces to the usual one while in other directions the formula gives the intensity of the diffuse scattering. The derivation is purely classical; each electron in the various atoms is assumed to scatter according to the J. J. Thomson formula and the amplitude of the resultant scattered wave is the vector sum of the amplitudes scattered by the individual electrons, the sum being taken over the entire crystal. The observed intensity is obtained by averaging over the orbital motion of the electrons and the thermal vibration of the atoms. No assumption is made as to the nature of either of these motions. This procedure leads to the *total intensity* (coherent+incoherent scattering) and from the nature of the resulting equation the incoherent part may be identified. As is well known, such a derivation by classical methods leads to the same result as a quantum-mechanical treatment except for corrections due to relativity, etc. Since these occur only in the incoherent part of the scattering they may be easily added.

WEDNESDAY MORNING AT 10:00 O'CLOCK

Sterling Hall, Room 111

26. The Reflection Coefficient of Mercury. R. C. MASON, *Westinghouse Electric & Manufacturing Company.*—Two new methods of measuring the rate of evaporation of liquid mercury show that the rate may be small compared to the kinetic theory calculated maximum rate, even though the mercury surface may appear clean and bright to the eye; this result may be interpreted as the mercury atoms having a large reflection coefficient. The first method uses a modified Chattock micromanometer to measure the change in pressure on a mercury pool when it is suddenly exposed to a nearby liquid air cooled condensing surface, and also to indicate the subsequent evaporation rate. From the two, the reflection coefficient may be calculated, independent of the calibration of the instrument, the temperature of the mercury surface, or the vapor pressure of mercury. Values of reflection coefficient from 0.93 to over 0.99 were obtained in this way. The second method employs an ionization gauge to measure the density of vapor between the evaporating mercury pool and the condensing surface. When the temperature of the mercury is measured by a thermocouple, the rate of evaporation may be found. Corresponding reflection coefficients from 0 to almost 1 have been observed.

27. The Infrared Absorption Spectra and Approximate Force Constants of Propene and Allene. LYMAN G. BONNER* AND ROBERT HOFSTADTER, *Princeton University.*—The present report marks the beginning of a systematic survey of the C=C force constant as it appears in various organic compounds. The infrared absorption spectra of gaseous propene and allene have been obtained with a rocksalt prism spectrometer in the region 1–15.5μ. Runs were taken with a 15 cm cell and under various pressure conditions ranging from 35 to 700 mm. Our measurements show bands in propene at 6211, 4386, 3021, 2309, 2008, 1815, 1634, 1435, 1183, 984, and 906 cm^{-1} and in allene at 6289, 4525, 3086, 2392, 1961, 1678, 1381, 1143, 1033, and 840 cm^{-1}. Approximate force constants have been calcu-

lated by the method of rigid groups, treating propene as an asymmetric triatomic molecule and allene as a symmetric linear-triatomic. The results of these calculations give the double bond force constant as 10.0 and 9.45×10^5 dynes/cm, respectively, in the two cases. For propene the calculations also furnish a value for the C−C force constant, in this case 3.8 in the above units.

* National Research Fellow.

28. Index of Refraction of Methane in the Infrared. R. ROLLEFSON AND R. J. HAVENS, *University of Wisconsin.*—The apparatus which was built to measure the index of refraction of HCl in the near infrared[1] has been improved so that it is now possible to make measurements out to 15μ. This improved apparatus has been used to measure the index of refraction of methane from 1μ to 15μ. The variation of the index in the neighborhood of the 3.3μ and 7.7μ bands shows that the ratio of the intensities of these bands is approximately 2.3. The overtone bands in the vicinity of 2.3μ contribute a noticeable but small amount to the index of refraction. No quantitative estimate of their intensity can be made, however, since several overtone bands occur in a narrow region of the spectrum where the rock salt monochromator has its smallest dispersion.

[1] Phys. Rev. **48**, 779 (1935).

29. The Products of Dissociation of Ethylene by Electron Impact. JOHN T. TATE, A. HUSTRULID AND P. KUSCH, *University of Minnesota.*—The dissociation of ethylene by electron impact has been investigated with a mass spectrograph. The ions which have been identified, their relative intensities at an electron energy of 75 volts and their appearance potentials are tabulated. It was not possible

Ion	Int.	A.P. (volts)	Ion	Int.	A.P. (volts)
$C_2H_4^+$	100	10.80±0.05	CH^+	2.5	22.9±0.5
$C_2H_3^+$	57.2	14.1 ±0.1	C^+	1.7	24.6±0.5
$C_2H_2^+$	51.3	13.4 ±0.2	H_2^+	0.13	22.4±1.5
C_2H^+	8.8	19.2 ±1.0	H^+	0.5	26.2±1.5
C_2^+	2.7	26.4 ±1.0			28.2±1.5
CH_4^+	0.06	——	$C_2H_4^{++}$	0.3	——
CH_3^+	0.6	——	$C_2H_2^{++}$	0.3	36.0±1.0
CH_2^+	5.2	19.2 ±0.3	C_2H^{++}	0.006	——

to identify the doubly ionized ions in every case, nor to determine their appearance potentials because of coincidences between these peaks and those due to singly ionized ions. The peaks CH_4^+ and H_2^+ have satellites whose appearance potentials are higher than those due to the main peak. These peaks may be accounted for by the assumption that two processes are responsible for the formation of these ions, with one of which a considerable amount of kinetic energy is associated.

30. The First Spark Spectrum of Tin: Sn II. W. W. MCCORMICK AND R. A. SAWYER, *University of Michigan.*—The low vapor pressure of tin makes the excitation of the higher terms of its spark spectrum difficult. Earlier investigators, notably Lang[1] and Green and Loring,[2] have been able to establish with certainty only a few of the lowest terms, with not more than two terms in any series. Thus, even the value of the ionization potential has been only approximate. The spectrum has been remeasured throughout the whole photographic region from 800A to 10,000A by using a hollow cathode discharge and long exposures. It has been possible to extend all the known series. In addition, the *F–G* series has been discovered, and five members found. The close agreement of the *G* terms with the Rydberg formula permits the determination of the ionization potential of Sn II as approximately 118,010 cm^{-1}, a change of about 300 cm^{-1} from the previous estimate. In all, about 80 new lines have been classified, determining about 25 new terms.

[1] Phys. Rev. **35**, 445 (1930).
[2] Phys. Rev. **30**, 574 (1927).

31. Spectral Series in Neutral Tungsten, W I, and Limitations Upon the Possibility of Determining Spectroscopic Ionization Potentials. O. LAPORTE, *University of Michigan,* AND J. E. MACK, *University of Wisconsin.*—The identification of $5d^46s7s\ ^7D_{12345}\ ^5D_{04}$ and $5d^46s8s\ ^7D_4$? leads to the series limit value W I $5d^46s^2\ ^5D_0$ (normal state) −W II $5d^46s\ ^6D_{\frac{1}{2}}=7.84$ volts; but probably the lowest level of W II is $5d^5\ ^6S$, some tenths of a volt below $^6D_{\frac{1}{2}}$, leading to a tentative value of 7.6±0.2 volts for the ionization potential. Among the complex spectra of atoms heavier than silver, series have been found only in Sa, Eu, and W. It seems quite likely that they can never be identified among the configurations involving partly filled *d*-shells ($n>4$) or *f*-shells except near the ends of the periods and near the very middle, i.e., with $d^5(^6S)nl$, $f^7(^8S)nl$, $d^4\ ^5D$, $d^6\ ^5D$, $f^8\ ^7F$, or $f^9\ ^7F$, alone or with one or two added *s*-electrons.

32. Collisions of the Second Kind and Sensitized Fluorescence of Tin and Mercury Atoms. J. G. WINANS AND R. M. WILLIAMS, *University of Wisconsin.*—Several tin lines have been observed in a low voltage Tesla discharge and in sensitized fluorescence. The discharge was produced in a fused quartz tube containing mercury and tin, and heated by a Bunsen burner. Tin lines were emitted from a region locally heated to about 900°C with a blow torch. In comparison with the arc spectrum of Sn, the following Sn lines in this discharge were enhanced over neighboring lines: 3262, 3034, 2840, and 2430. All enhanced lines except 3034 originate from Sn levels nearly equal in energy to Hg levels. Sensitized fluorescence of Sn was obtained by heating a drop of tin in the tube with a hydrogen-air blow torch and illuminating with light from a Hanovia SC-2537 tube. Mercury pressure was regulated with a Bunsen burner. The Sn lines observed are listed below with estimated intensities in parentheses. 4524 (2), 3801 (3), 3331 (4), 3262 (10), 3175 (4), 3034 (10), 3009 (2), 2863 (3), 2840 (10), 2706 (10), 2661 (4), 2547 (2), 2430 (4). All Sn lines excepting again 3034 arise from levels with low energy discrepancy with Hg 2^3P_2, 2^3P_1, or 2^3P_0. The average thermal energy available for excitation was 0.101 volt. The pressure of Sn vapor was less than 5.6×10^{-5} mm of mercury.

33. The Perpendicular Vibration Bands of NH_3. E. F. BARKER, *University of Michigan.*—The two parallel vibrations of NH_3 are well known both from infrared and from Raman observations. They yield bands at 3μ (ν_1) and at 10μ (ν_3). The intense band at 6μ corresponds to one of the perpendicular vibrations (ν_4). Its structure has been observed in detail, and is found to correspond exactly with the theoretically predicted pattern, both as to locations and as to intensities of the lines. The center is at 1626 cm^{-1}. The position of the other fundamental (ν_2) has not previously been determined. By means of two combination bands, one at 2.2μ ($\nu_2+\nu_3$) and the other at 4.0μ ($\nu_2-\nu_3$) the characteristic structure of which can be recognized, it is now possible to determine this band exactly. Its center is at 3407 cm^{-1}. The fundamental itself is weak, and is difficult to observe because of the intense parallel band ν_1 which overlies it. A band has also been found corresponding to the Raman line observed in gaseous ammonia at 3219 cm^{-1}. This is interpreted as the parallel component of $2\nu_4$.

34. X-Ray Spectroscopic Data in Regard to the Electronic Energy Bands in Potassium and Sodium Chloride. JOSEPH VALASEK, *University of Minnesota.*—The K beta lines of chlorine in the chlorides of sodium and potassium have been measured. Long exposures were given to record the weaker lines and an attempt has been made to fit the group into an energy band scheme of the usual type. The principal line offers little difficulty and gives the binding energy of the Cl^- $3p$ electrons. The longer wave-length satellites may come from the Na^+ $2p$ and the Cl^- $3s$ levels, though the numerical agreement with published calculations is not particularly good. The first two satellites on the short wave-length side indicate energy levels at elevations above Cl^- $3p$ which agree roughly with the wave-lengths of the F and U bands in the colored crystal. The other short wave-length satellites are probably due to double ionization.

35. The Second Order Null Result of the Michelson-Morley-Miller Experiment. W. B. CARTMEL, *Université de Montréal.*—In Lorentz's triangle the two rays from a point P meet again at the same point P on the plate. In Silberstein's triangle[1] the two rays from the point P meet again at a point P' in the ether, at a distance lv^2/c^2 beyond the second position of P, and there is therefore no v^2/c^2 difference of phase between the two wave fronts that intersect at the point P'. This justifies Lorentz's theorem. The wave front reflected at the point where ray BP' meets the plate is parallel to the wave front in arm A that passes through P', but there is a third order difference in position. The third order term is due to the use of a fixed source instead of a terrestrial source. The same v^3/c^3 effect comes in if we use an inclined ray from a terrestrial source, in which case the experiment is not ideal. A fringe shift is indicated by the ray BP' in Silberstein's triangle meeting the plate at a distance lv^2/c^2 from the point P', but this is almost annulled. Lengthening arm B would cause the ray to move further up the plate and increase the fringe shift. Neither arm is actually lengthened but there is an increase in path length in arm A relatively to arm B, and this moves the end point of the ray *down* the plate so that the rays PBP and PAP meet at the plate as in Lorentz's triangle. The $\frac{1}{2}v^2/c^2$ term in Silberstein's equation comes from the virtual rotation of the 45° plate which moves the ray up the plate, and the virtual change in length of arm brings it back again, giving us a v^2/c^2 null result, together with a v^3/c^3 fringe shift.

[1] L. Silberstein, *The Theory of Relativity* (Macmillan, London, 1914), p. 89.
[2] H. A. Lorentz, *The Theory of Electrons* (Stechert, New York, 1916), p. 181.

SUPPLEMENTARY PROGRAM

When two or more papers are offered by the same member one only of these will be assigned a place on the regular program while the others will be placed in a supplementary program to be called for if time permits.

Papers received after the program has been printed will be placed in the supplementary program.

The papers in the supplementary program may be called for only at the session indicated.

36. Is the Null Result Inherent in the Interferometer or in the Motion? W. B. CARTMEL, *Université de Montréal.**— Let us consider the motion of the observer and of the source separately, as was done by Voigt.[1] We shall take the motion of the observer to be along a tangent to a great circle on one of the concentric spherical wave surfaces emanating from a point source S. The ray at right angles to the motion meets the observer at the point where the tangent meets the radius, the observer's motion beginning at the point of intersection of the secant and the tangent. The source, moving with the same speed as the observer, finds itself at a point S', at the end of the longer diagonal of a parallelogram, at the instant of time when the ray meets the observer. The two sides of the parallelogram give us the two positions of the apparent ray joining source and observer. Measuring from S' along the apparent ray to the wave surface, we shall find a distance $l(1+v^2/c^2+\frac{1}{4}v^4/c^4+\cdots)$, and from the same point, along the apparent ray in the direction of the motion, a distance $l(1+v^2/c^2+v^4/c^4+\cdots)$. To the second order our wave surfaces are circles, a result similar to Voigt's.[1] This is on axes fixed in the ether. On axes moving with the earth the radius to the wave surfaces is given by the latter expression in both directions, which is identical with a result found with the interferometer,[2] but inherent in the motion.

* To be called for after Paper No. 35.
[1] W. Voigt, Göttinger Nachrichten, 1–21, 41 (1887).
[2] W. B. Cartmel, Phys. Rev. **49**, 647, 649 (1936).